The Pathway to Zero Emission Fossil Fuel Power Plant

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US CO2 Capture and Sequestration Conference Pittsburgh

7-10th May 2007

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Agenda

1st topic	Strategy and Drivers
2nd topic	Capture Technologies and Power Plant
3rd topic	Other Important Issues
4th topic	A European Perspective
4th topic	Some concluding remarks

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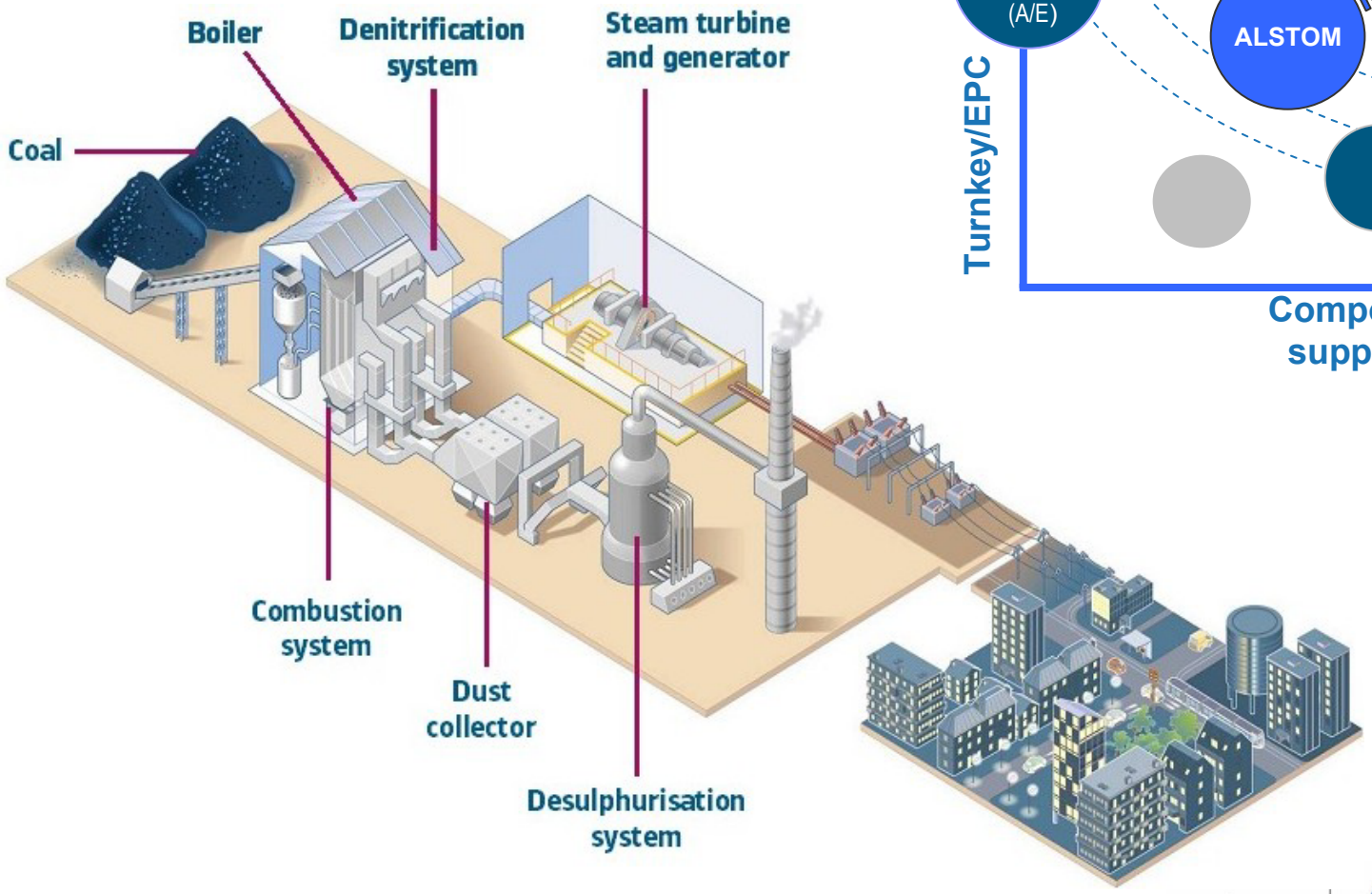
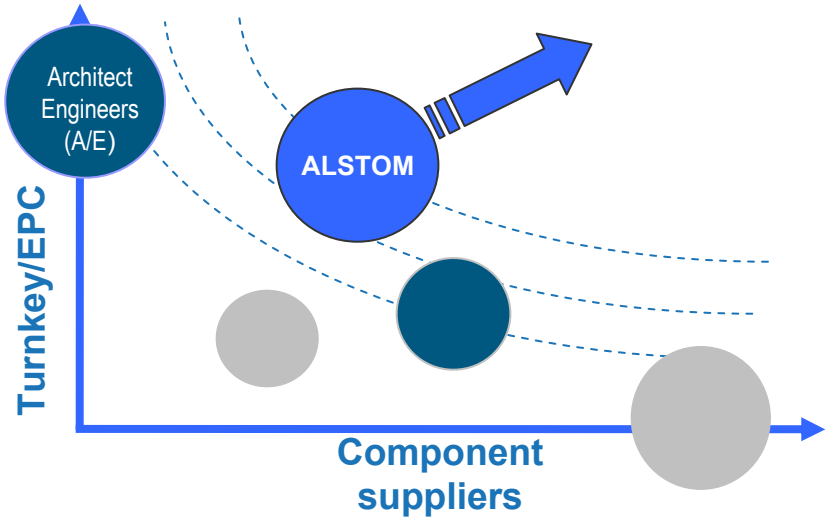
A Power Generation System Provider Perspective





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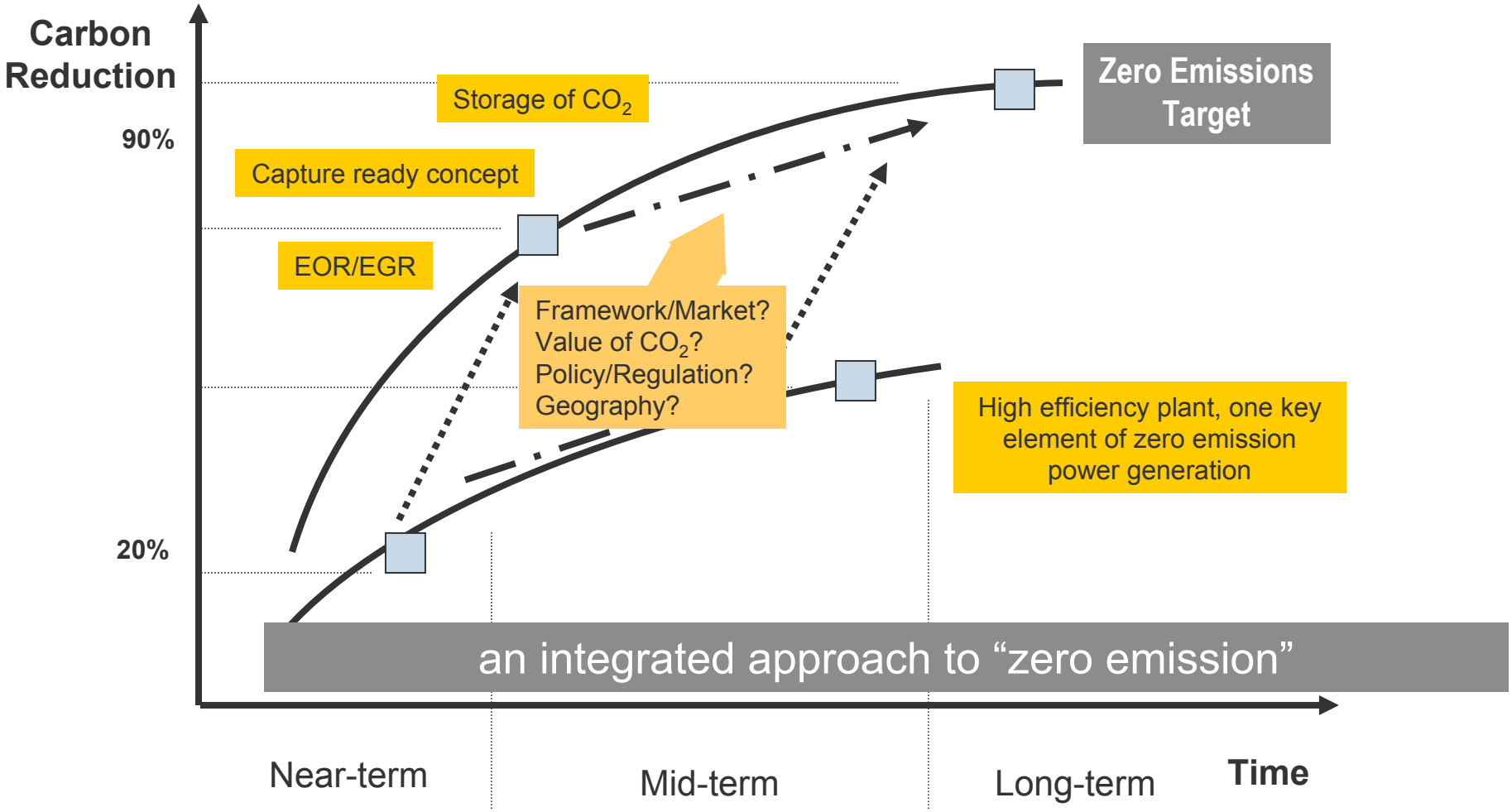
Some key touchstones

- **Importance of clean use of fossil fuels**
  - a critical transitional issue in getting to a sustainable energy future
  - an essential part of the portfolio
- **Importance of accelerating the take-up of clean fossil**
  - need for incentives for early action on `zero emission` power plant
  - stable financial and regulatory framework to get “many of a kind”
- **Importance of addressing issue worldwide**
  - use of high efficiency technologies, and …….
  - ……. prepare the way `zero emission`
    - retrofitting of high efficient coal plant with capture to avoid “carbon lock-in”
    - how to ensure new plant is “capture ready”
    - increase use of low carbon technologies

Pathway to zero emission power for fossil fuels



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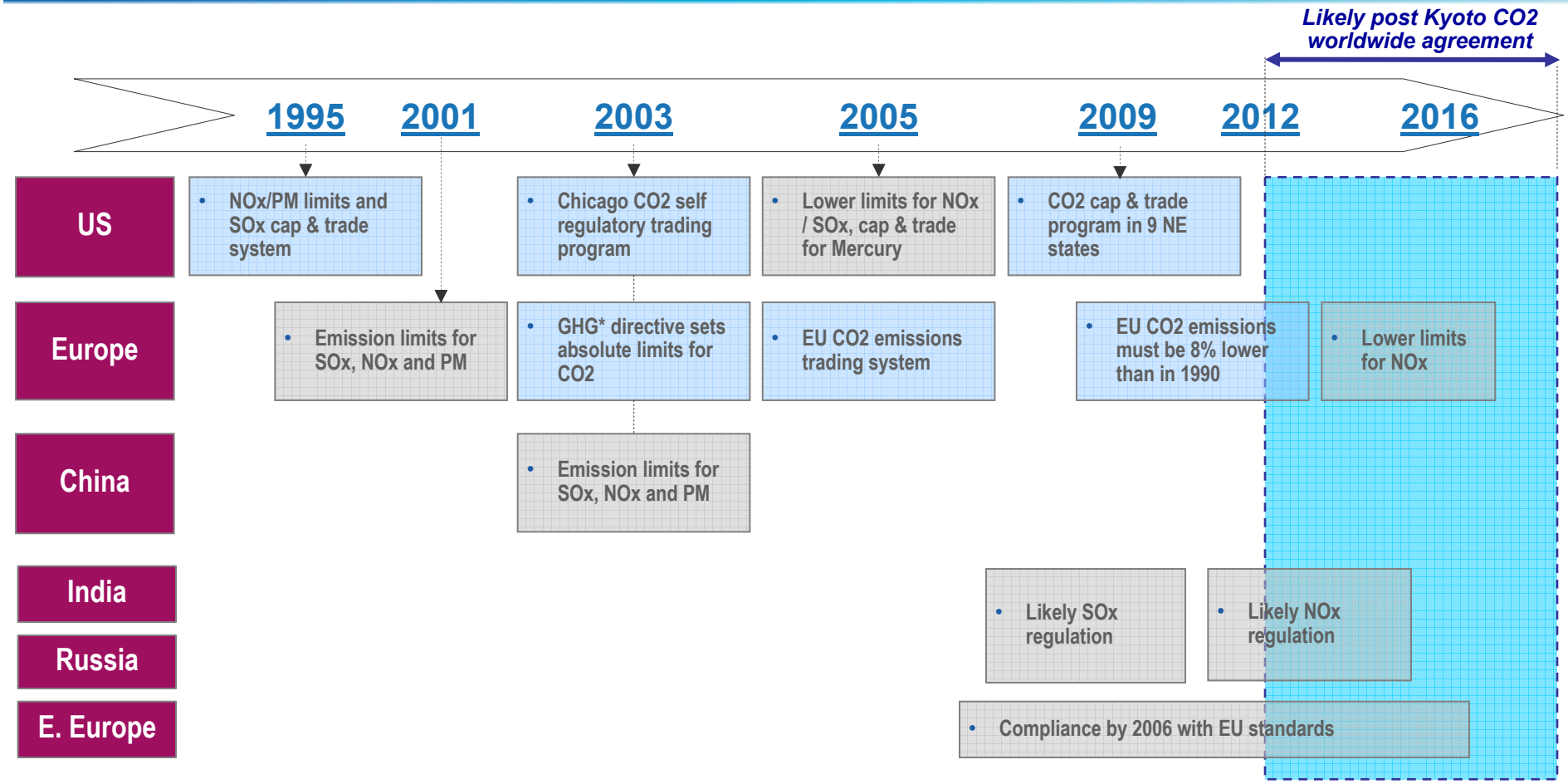
Environmental legislation – a main driver for change



Traditional pollutant legislation driving US/Europe market
CO2 constraints are becoming the driving factor worldwide

Source : IPCC, ALSTOM analysis

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The ALSTOM CO2 STRATEGY

- Efficiency of installed base
- Advanced cycles for new plants
- CO2 ready power plant
- Retrofitable CO2 capture solutions

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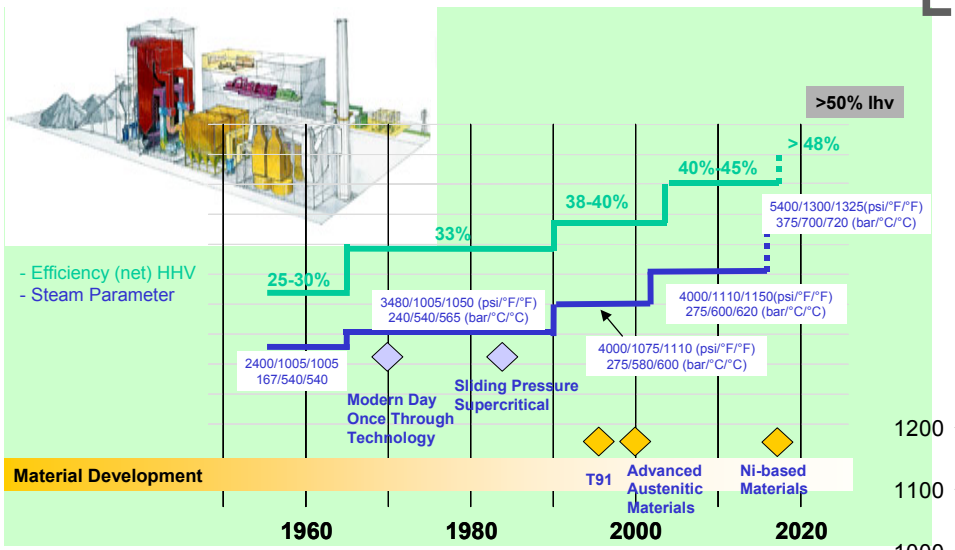
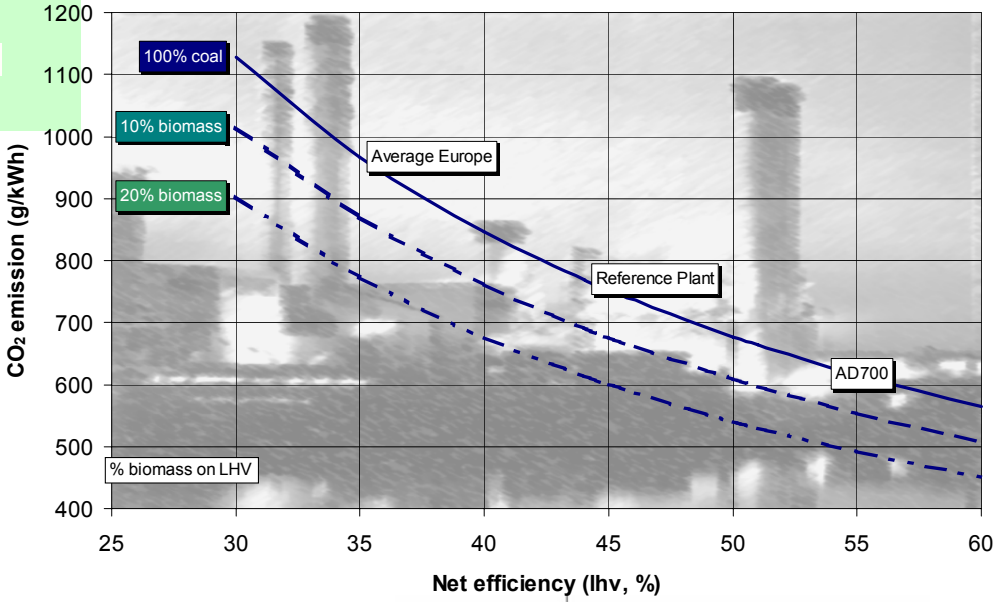
Carbon Abatement Technologies

Efficiency Improvement



Co-firing/Fuel Flexibility



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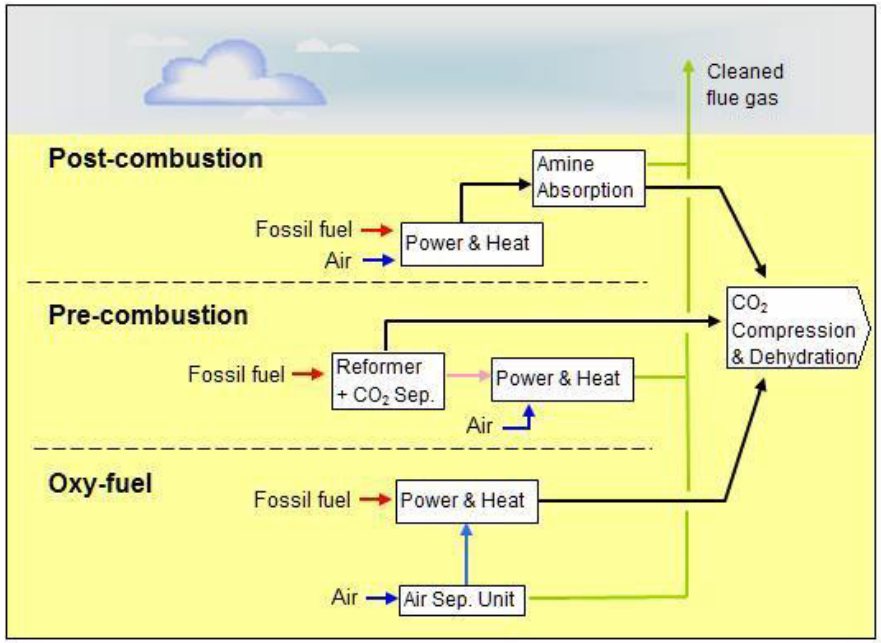
Carbon Capture Technologies

- Accepted need for a portfolio
- All technologies need to be addressed
- Both retrofit and new plant



Efficiency reduction: goal < 5%-points
Cost of CO2 avoided: goal < 20 Á/t CO2

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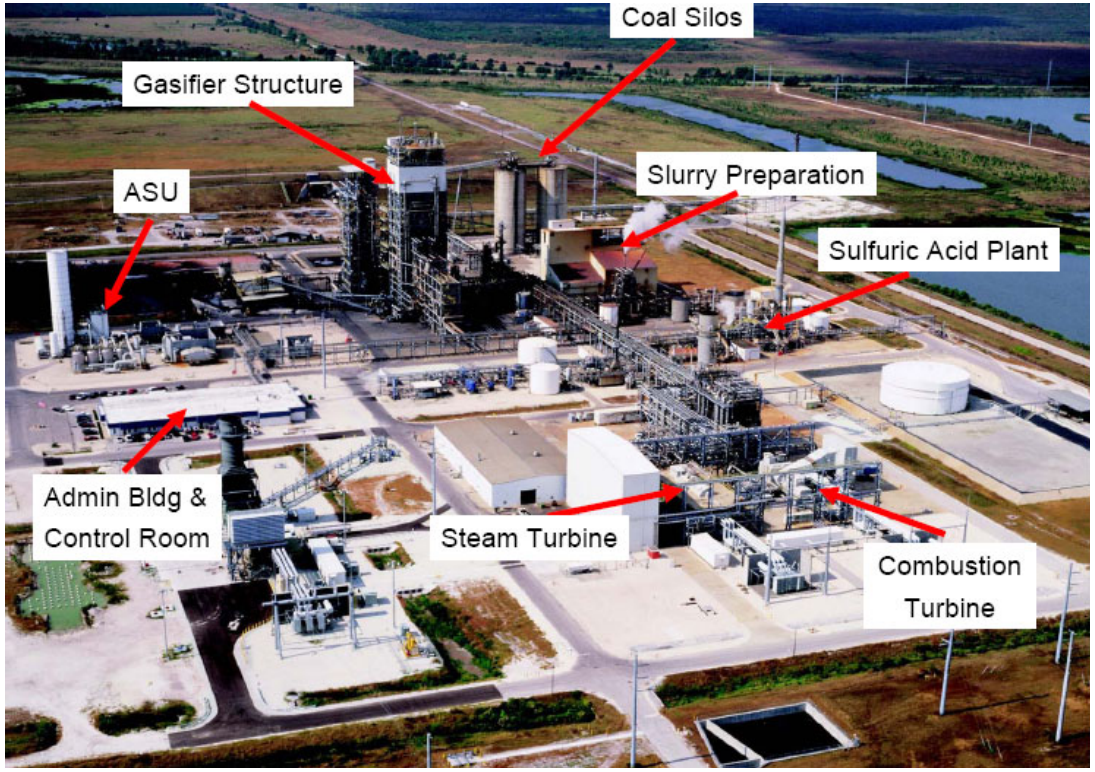
CO2 CAPTURE SOLUTIONS
Pre Combustion Solution for New Plants: IGCC+Capture

Coal gasification



Tampa Electric Company, Polk Power Station, 252 MWe, Mulberry, USA (FL)

- CO2 Capture technology is proven and economical in other industries
- High Capital and Operating Costs
- Limited operation flexibility
- Plant retrofit: not generally possible
- Landspace 1,5 x PC plant for same MW

Hydrogen-fired gas turbines

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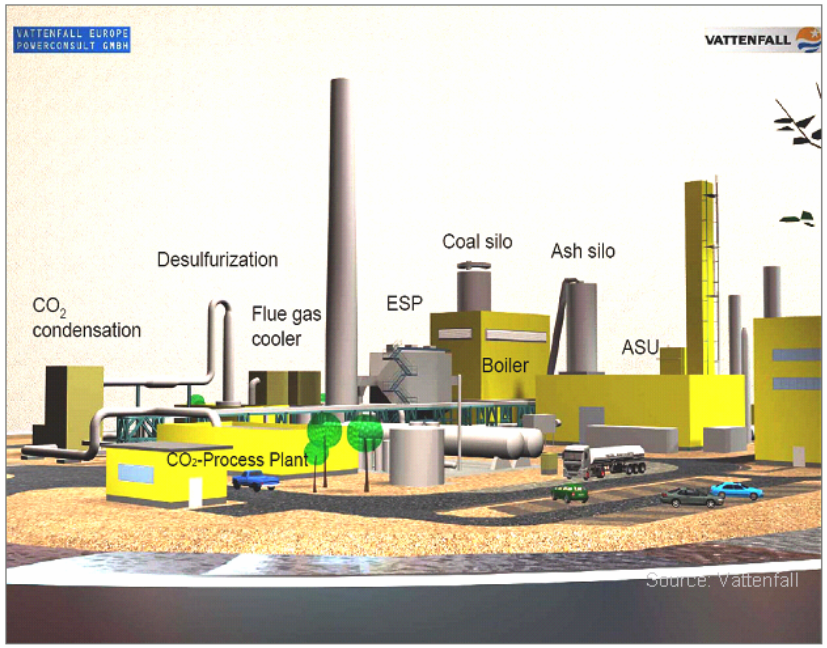
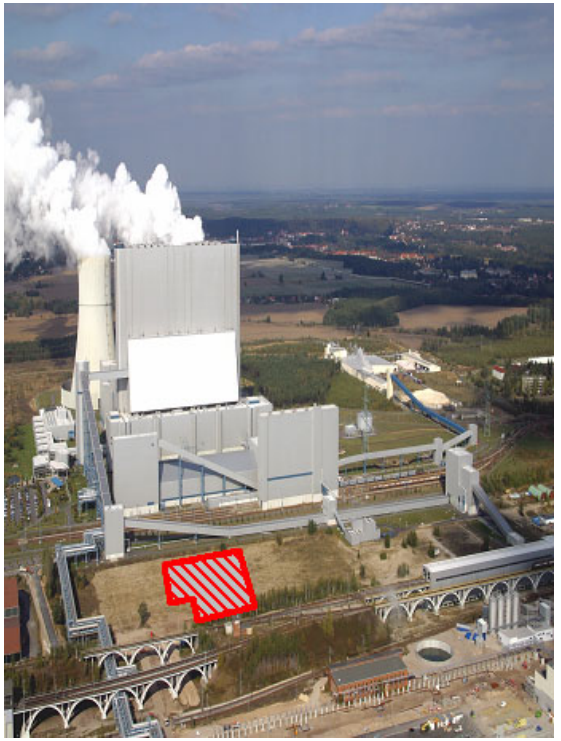
CO2 CAPTURE SOLUTIONS
Oxy-combustion: 30 MW_{th} Oxyfuel Pilot Plant

CO_2-free coal-fired pilot plant at ÂSchwarze Pumpe“ site based on Oxyfuel technology (planned operation: mid 2008)





- Large quantity of O2 required
- CO2 separation with no use of chemicals
- Smaller boiler and flue gas volume reduction (Low NOx)

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CO2 CAPTURE SOLUTIONS
Post Combustion Solutions for New Plants and Retrofit

CO_2 absorption processes (MEA, MDEA)

PP Esbjerg (DK)

1 t CO_2/h pilot plant (CASTOR EU-FP6)

- Available in commercial scale
- Retrofitable and flexible
- High energy demand for regeneration of solvents

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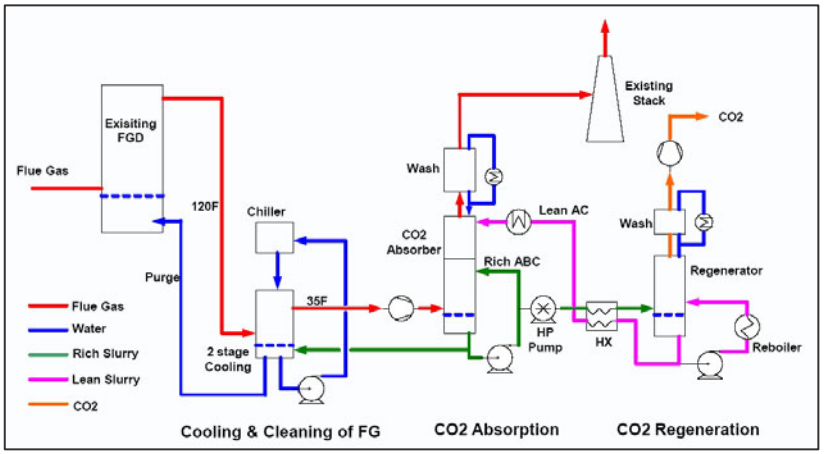
CO2 CAPTURE SOLUTIONS
Chilled Ammonia Process

A promising technology for post combustion carbon capture



Principle

- Ammonia (NH_3) reacts with CO_2 and water. It forms ammonia carbonate or bicarbonate
- Moderately raising the temperatures reverses the above reactions – releasing CO_2

Advantages

- High efficiency capture of CO_2 and low heat of reaction
- Low cost reagent
- No degradation during absorption-regeneration
- Tolerance to oxygen and contaminations in flue gas

5 MW Pilot Plant (USA) Start-up anticipated for 2007

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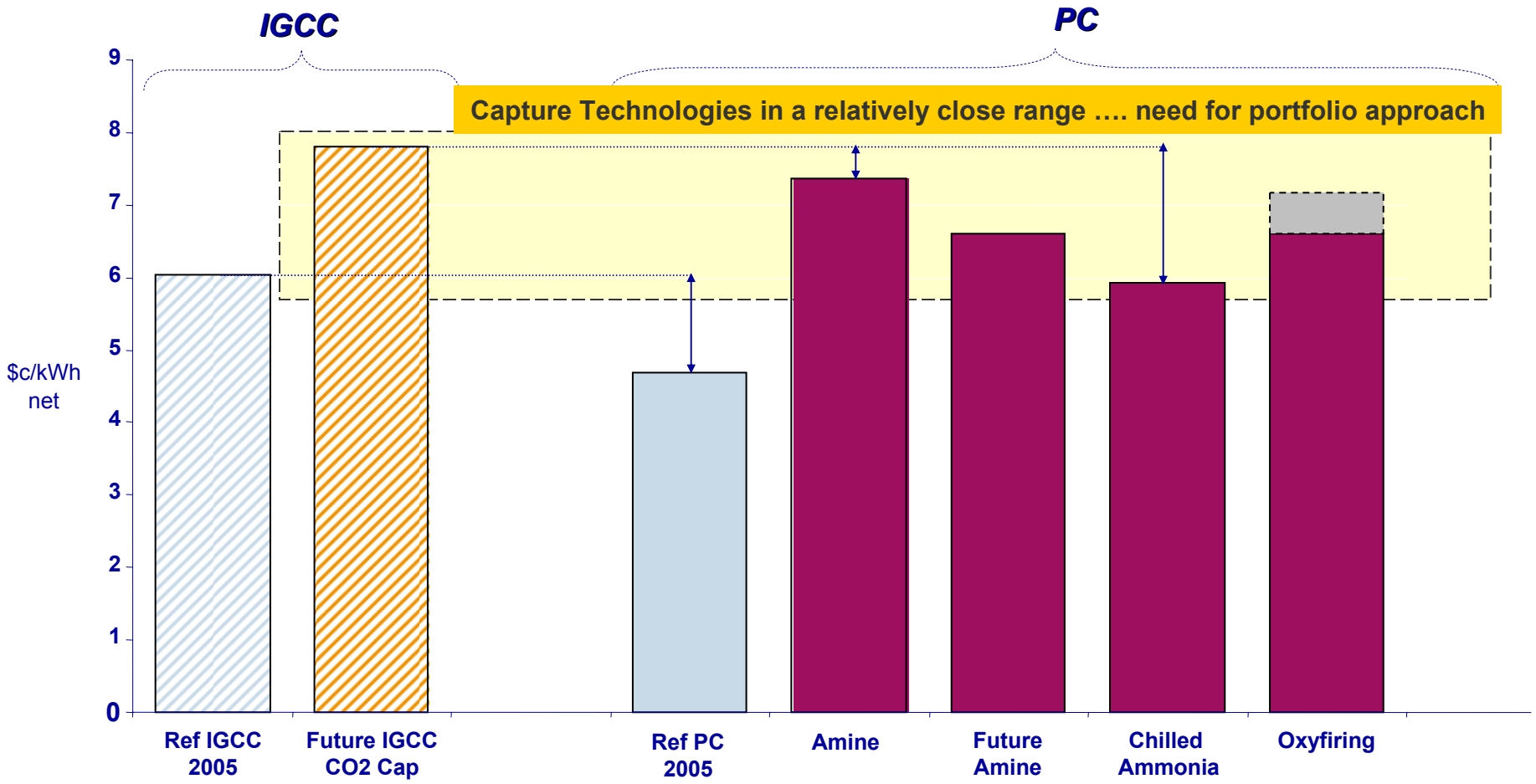
Cost of Electricity :
800MW Coal Plant Comparisons



CO_2 capture technologies impact plant performance

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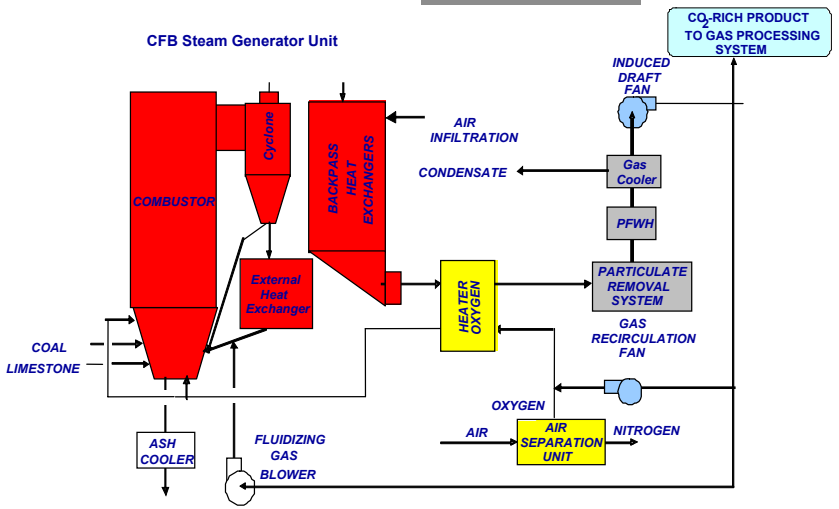
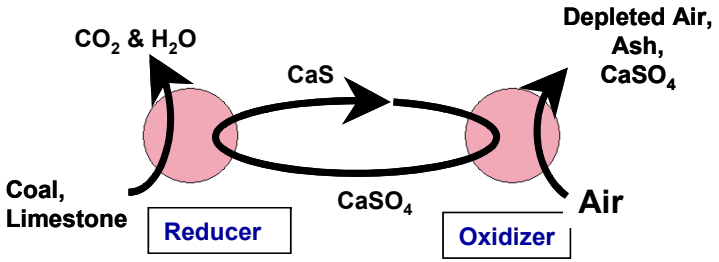
Advanced Capture Processes

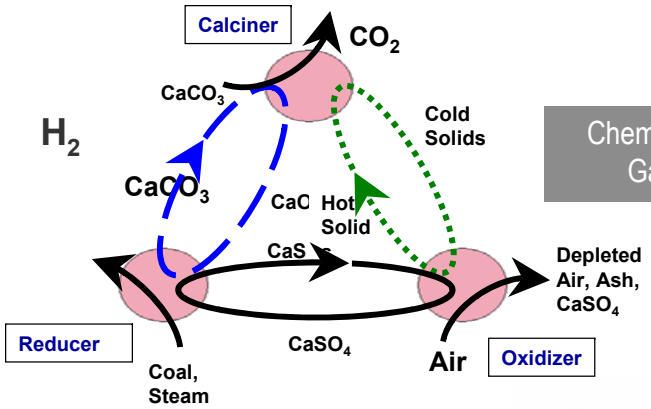
- Oxygen Fired CFB
- Chemical Looping
  - Combustion
  - Gasification

O_2 fired CFB





Chemical Looping Combustion



Chemical Looping Gasification

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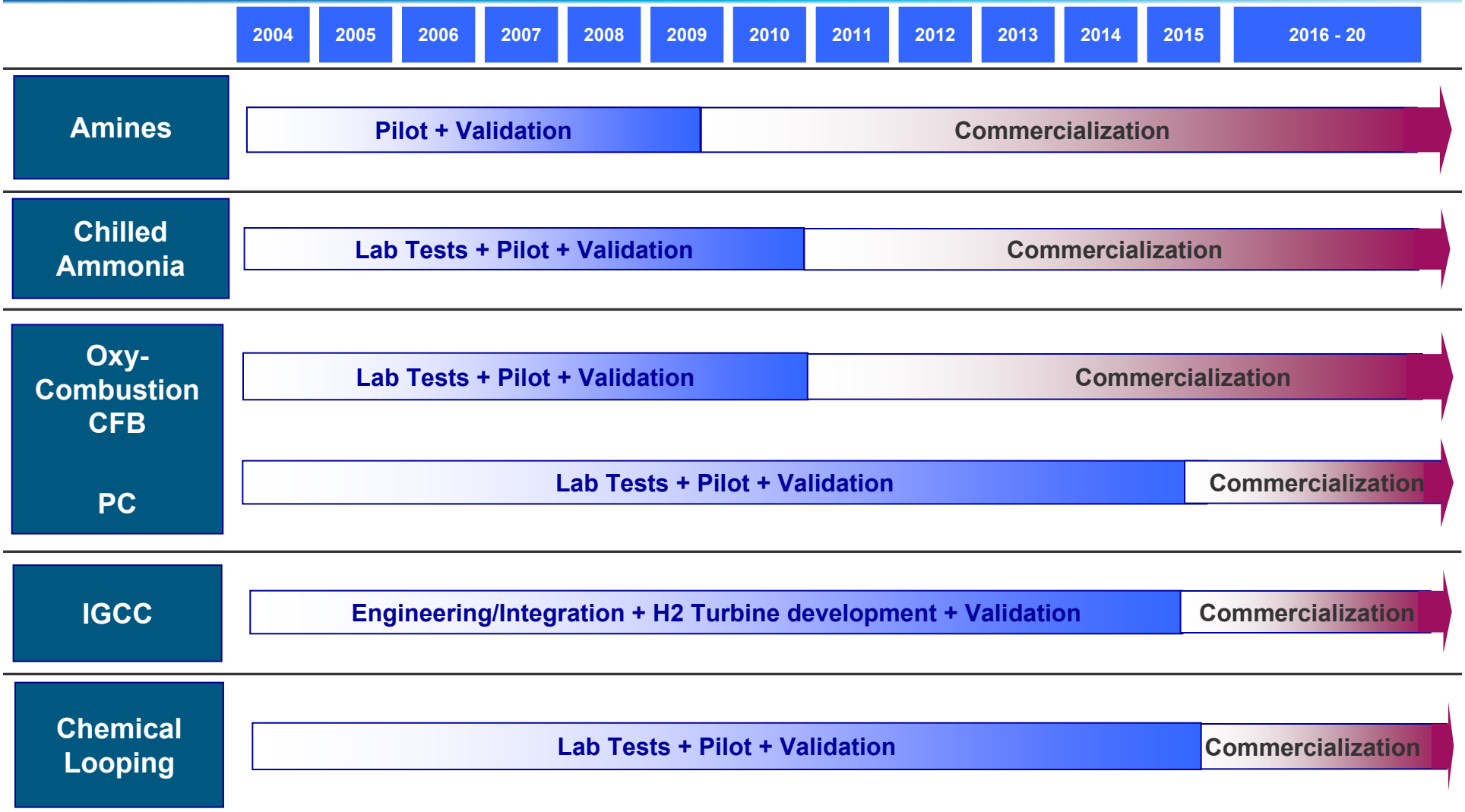
CO2 CAPTURE SOLUTIONS

Time-line of CO_2 Capture Processes



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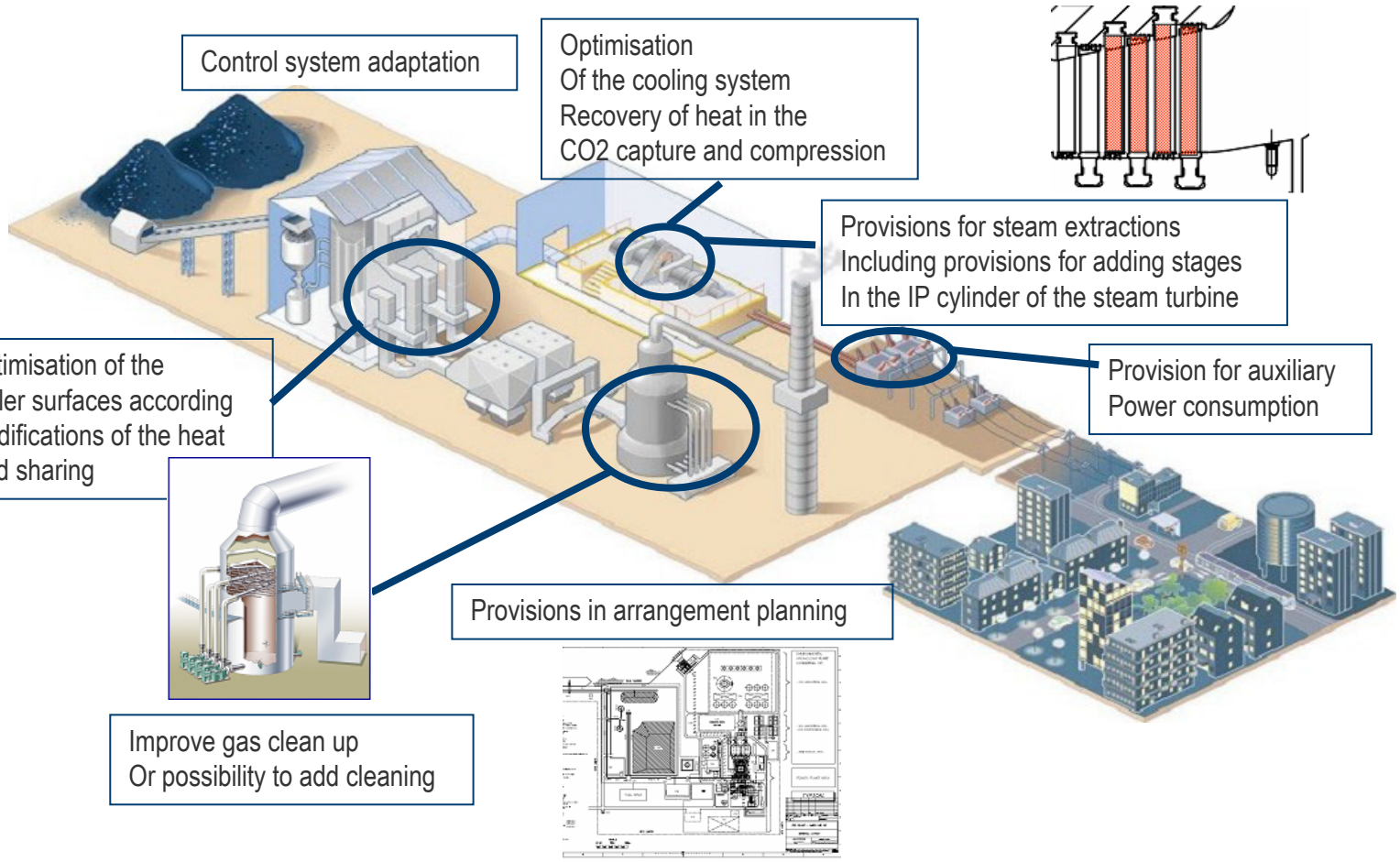
CAPTURE READY
CO_2 "Capture Ready" Coal Power Plant



Insure CO2 readiness of current power plants

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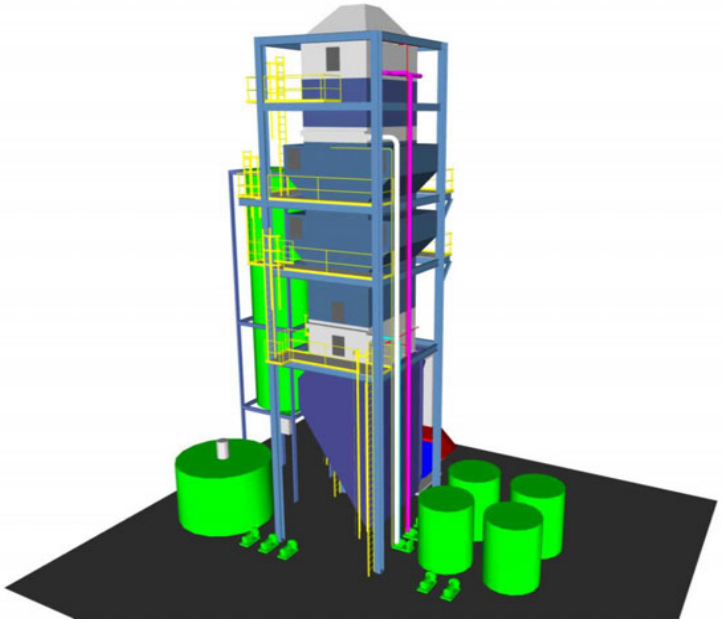
Multi-pollutant Control Systems

- Integrated APC system based around commercially proven and reliable technologies
- Uses readily available reagents
- Produces reusable byproduct(s)
- Superior cost/performance ratio:
  - Extremely compact design
  - Fewer moving parts reduces maintenance
  - Superior environmental performance
- Targeted emissions levels:
  - SO_2: 0.02 lb/MMBTU (> 99.5%)
  - Hg: 1.0 lb/TBTU (> 90%)
  - PM: 0.01 lb/MMBTU (99.99%)
  - NO_x: 0.05 lb/MMBTU w/SCR



Controls SO_x, $PM_{10}/PM_{2.5}$ Mercury & NOx

Not just CO_2

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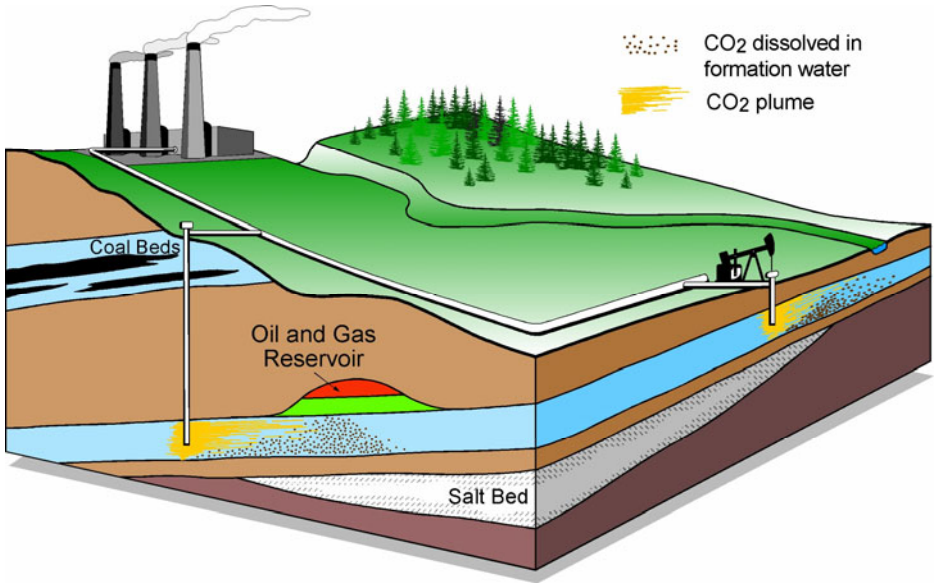
CO_2 Transportation and Storage

Key Issues

- Cost Reduction
- Public Acceptance
- Safe and Effective Storage
- Developing the Legal, Regulatory & Fiscal Framework



Safety and acceptance of CO_2 storage

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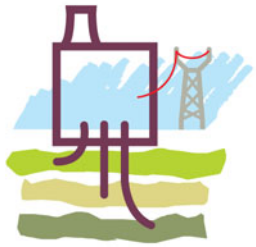
ZEPG/CCS Actions in Europe



ZEP : Set-up and Vision

The Vision: To enable European fossil fuel power plants to have zero emission of CO_2 by 2020.

- **Primary task to set strategic research agenda (SRA) and deployment document (SDD) for a major European action**
- **Advisory Council formed in June 2005**
  - **6 Generators**: E.ON, Endesa, Enel, Energi E2, RWE, Vattenfall
  - **6 Equipment suppliers**: Ansaldo, ALSTOM, Air Liquide, Foster Wheeler, Doosan Babcock, Siemens
  - **5 Oil and Gas**: BP, Shell, Statoil, Total, Schlumberger
  - **5 Research**: BGS, CIRCE, IFP, Polish CMI, GEUS
  - **3 NGOs**: Bellona, Climate Action Network Europe, WWF
  - Chair: Kurt Haege/Vattenfall Vice-Chairs: Olivier Appert/IFP, Gardiner Hill/BP, Charles Soothill/ALSTOM, Frederic Hauge/Bellona
- **Formally launched 1st December 2005**
- **First General Assembly 12-13th December 2006**

www.zero-emissionplatform.eu

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ZEPG/CCS Actions in Europe

- Acceptance by EU Spring Council
- Specific reference to need to establish a series of CCS demos : a “ZEP Flagship Programme”
- Mentioned in communique from EU-US Summit in May 2007

ZEP

STRATEGIC RECOMMENDATIONS

Major input to EC Energy Package of 10th January 2007 especially the Communique on Sustainable Power Generation from Fossil Fuels

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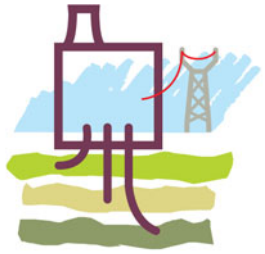
ZEPG/CCS Actions in Europe



ZEP : Flagship Programme

A portfolio approach needed to generate confidence to do CCS at scale

Fuel type
1. Coal
2. Gas
3. Biomass-Other

CO_2 capture technology
1. Pre-combustion (2options)
2. Post-combustion (>2options)
3. Oxy-fuel (>2options)

Infrastructure
1. Offshore
2. Onshore

Storage type
1. Depleted oil & gas fields
2. Saline formations
3. Enhanced oil recovery (EOR)
4. EGR / ECBM / Deep coal

	Oxy-fuel (>2x)	Pre-combustion (>2x)	Post-combustion (2x)
Infrastructure			
• Offshore	✓	✓	✓
• Onshore	✓	✓	✓
Coal			
• Depleted oil & gas		✓	
• Saline formation	✓		
• EOR			✓
• EGR / ECBM / etc	✓		
Gas			
• Depleted oil & gas			✓
• Saline formation		✓	
• EOR	✓		
• EGR / ECBM / etc			✓
Biomass - Other			
• Depleted oil & gas			✓
• Saline formations		✓	
• EOR		✓	✓
• EGR / ECBM / etc	✓		

Multiple technology combinations demand a programme approach

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Concluding Remarks : CO2 Summary
an integrated approach

	Near Term	Medium to Long Term
Installed base	• Integrated retrofit offerings with higher efficiency and STs • Fuel switch • Biomass co-firing	• CO2 post-combustion capture products: amine, ammonia, oxy-combustion for retrofit • Advanced cycles retrofit
New power plants	• Fuel flexibility via CFBs • 620 C best available technology for improved efficiency • CO2 ready power plant concept	• Integrated CO2 post-combustion capture or oxy-fuel firing and chemical looping • 700 C USC boilers & STs • Gasification for polygeneration

Clean Combustion = limiting emissions while maintaining power plant economics

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